arXiv:astro-ph/9512056v1 11 Dec 1995

# The X-ray spectrum of the $\gamma$–bright quasar S5 0836+710

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**Abstract.** We present the results of an ASCA observation of the high redshift flat spectrum radio quasar S5 0836+710. The $\sim 0.4 - 10$ keV X-ray spectrum is remarkably flat with $\Gamma \sim 1.4$ and substantial intrinsic absorption at low energy. The spectral slope was found to be in good agreement with the non–simultaneous ROSAT PSPC observations while no evidence of intrinsic absorption has been found in the PSPC spectrum. Our results suggest time variability of the absorbing material on timescales less than five months in the source rest–frame.

## 1. Introduction

The flat spectrum radio quasar S5 0836+710 is a distant ($z = 2.172$) strong radio source ($S_{5\mathrm{GHz}} = 2.67$ Jy) showing superluminal components in a bright, one-sided VLBI jet and high radio polarization (Kühr et al. 1981). The optical polarization is low ($1.1 \pm 0.5\%$; Impey & Tapia 1990), while strong optical variability has been detected in early 1992, including a rapid flare on February 16 (von Linde et al. 1993). It is one of the most luminous sources discovered by CGRO–EGRET observatory in the hard $\gamma$–ray band, being the highest redhift source among the about 50 blazars so far discovered by EGRET (von Montigny et al. 1995). The $\gamma$–ray spectrum in the energy range $\sim$ 30 MeV – 2 GeV is very steep with a photon index $\Gamma \simeq 2.4 \pm 0.2$ (Thompson et al. 1993). Subsequent EGRET observations (Nolan et al. 1996), confirm the steep spectrum ($\Gamma = 2.62 \pm 0.36$) and significant flux variability without associated spectral variations.

In the X-ray band S5 0836+710 has been previously observed by the ROSAT PSPC in the $\sim 0.1 - 2.0$ keV band. The count rate decreased by a factor of $\sim 2$ on a timescale of $\sim 7$ months (observer frame) between the two pointed observations (Brunner et al. 1994). The soft X–ray spectrum is the flattest among the radio–loud quasars studied by Brunner et al. and is well described by a single power law in both the observations with $\Gamma \simeq 1.40 \pm 0.05$.

The extreme X– and $\gamma$–ray spectral properties of S5 0836+710 make this source an ideal target for the study of the high energy properties of blazars. In the following the results of the spectral analysis of an ASCA observation are presented and compared with the ROSAT data.

## 2. ASCA observation and data reduction

ASCA observed S5 0836+710 on 1994 March 17 with the GIS for a total effective exposure time of about 16500 s and with the SIS for about 10500 s. Due to an attitude problem at the beginnig of the observation the data collected in the first 5 ksec have been removed from the present analysis. The SIS was operated in 1 CCD mode and all the data were collected in FAINT mode and corrected for DFE and echo. Source counts were extracted from a circle centered on the source of $6'$ radius for the GIS and $3'$ for the SIS. Background counts were collected from the blansky files for GIS (from a region uncontamined by NGC 6552 and at a similar off-axis distance of the source) and from the same field of view for the SIS. Backgrounds selected in a different way gave results consistent with the analysis presented in the following. Data preparation and analysis have been performed using the XSELECT package, and the extracted spectra were analyzed using version 8.5 of XSPEC.

### *2.1. ASCA Spectral Analysis*

No significant variability has been detected in the GIS and SIS light curves, therefore the spectra have been collected for the whole observation. The pulse height spectra were binned in order to get at least 20 counts per bin for the GIS and SIS detectors and the adopted energy range were limited to 0.7–10 keV and 0.4–10 keV respectively.

A single absorbed power law was fitted to the data leaving first the column density free to vary and then fixed at the Galactic value (Table 1). We note that the two GIS (2 and 3) and the two SIS (0 and 1) give very consistent results; therefore we also fitted simultaneously both instruments. Confidence contours in the parameter space $N_H - \Gamma$, for the simultaneous fit, are shown in Fig. 1.

The power law model provides a good fit to the GIS data leaving essentially unconstrained the absorbing column density due to the limited low energy GIS response ($> 0.7$ keV). Significant evidence of intrinsic absorption was found in the SIS data where a power law fit with the column density fixed at the Galactic value can be rejected at $> 99.9\%$ confidence (F–test). Fitting the SIS data with $N_H \equiv N_{HGal}$, the slope becomes flatter by $\Delta\Gamma \simeq 0.1$, and systematic residuals appear at soft energies. We have also performed spectral fitting taking into account the source

**Table 1.** GIS and SIS - Power Law Fits

| *Instrument* | $\Gamma$ | $N_{\rm H}^{\rm a}$ | $\chi^2$ |
|---|---|---|---|
| $GIS2+3$ | $1.42 \pm 0.10$ | $< 14.7$ | 0.89/241 |
| $GIS2+3$ | $1.38 \pm 0.04$ | $2.78^b$ | 0.89/242 |
| $SIS0+1$ | $1.46 \pm 0.08$ | $12.2 \pm 3$ | 0.79/257 |
| $SIS0+1$ | $1.27 \pm 0.04$ | $2.78^b$ | 0.94/258 |
| $GIS+SIS$ | $1.45 \pm 0.05$ | $11.4 \pm 3$ | 0.87/503 |
| $GIS+SIS$ | $1.32 \pm 0.03$ | $2.78^b$ | 0.97/504 |

[a] Units of $10^{20}$ cm$^{-2}$, [b] Galactic column density.

redshift. The best fit value for the absorbing column density in the source rest frame is $N_H \simeq 1.2 \pm 0.4 \times 10^{22}$ cm$^{-2}$, while the power law slope remains flat, $\Gamma = 1.43 \pm 0.07$, up to $\sim 30$ keV. An extrapolation at high energies of the best fit power law requires a sharp spectral break of $\Delta\Gamma \sim 1$ in the range 4–8 MeV in order to be consistent with the EGRET measurements. The derived luminosity in the 2–10 keV band quasar frame is $\simeq 6 \times 10^{47}$ ergs s$^{-1}$ corresponding to an observed flux of $\simeq 1.4 \times 10^{-11}$ ergs cm$^{-2}$ s$^{-1}$. No evidence of an iron emission line is present in the GIS or SIS spectra with a tight upper limit for the equivalent width EW $\leq 31$ eV (90% confidence).

### *2.2. ASCA and ROSAT Spectral Analysis*

To better compare the ASCA spectral fitting results with the ROSAT PSPC data we have extracted from the public archive the two available pointed observations (March 92 and November 92). The two ROSAT observations give similar spectral parameters allowing a simultaneous spectral fitting. The best fit value for the absorbing column density is consistent with the Galactic one (Fig. 1) and the derived power law slope $\Gamma = 1.41 \pm 0.04$ with $N_H \equiv N_{HGal}$ is in very good agreement with the findings of Brunner et al. (1994). ¿From a comparison of the confidence contours in the $N_H - \Gamma$ parameter space, we find that the power law slopes agree within 90%, but the column densities obtained with ROSAT and ASCA are significantly different. This large difference, a factor of $\sim 4$, cannot be accounted for in terms of a systematic error in the SIS low energy calibration estimated to be $\sim 3 \times 10^{20}$ cm$^{-2}$.

## 3. Discussion

Even assuming the ASCA SIS systematic uncertainty in determining the soft X-ray absorption column, the spectrum of S5 0836+710 requires absorption in excess to the Galactic value. Alternative models have been considered as well. A broken power law cannot be excluded with the present data but seems unlikely because the strong depletion of the data in the lower channels requires an unplausibly reversed slope with $\Gamma < 0.4$ in the soft energy band.

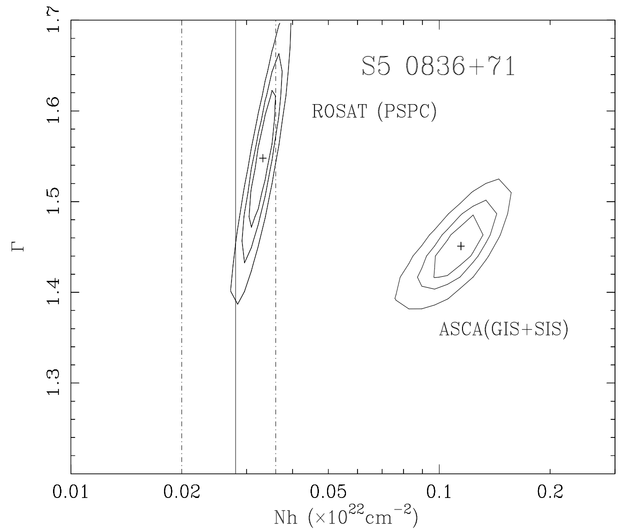


**Fig. 1.** 68%, 90%, 99% confidence contours in the $N_H - \Gamma$ plane. The vertical lines indicate the Galactic column density and estimated 30% error (Dickey & Lockman 1990).

A full discussion of this and other models is deferred to Cappi et al., in preparation. The ASCA spectrum, combined with the ROSAT data, provide a strong evidence for variable absorption in the direction of S5 0836+710 on a time scale $< 5$ months (quasar frame). S5 0836+710 would not be the first high redshift radio-loud quasar which exhibit intrinsic absorption (Elvis et al. 1994) or variable absorption (NRAO 140, Marscher 1988). A Galactic origin for the variable absorption in NRAO 140 has been suggested by Turner et al. (1995) combining the atomic and molecular (CO) column densities along the line of sight to the quasar, through the Perseus cloud complex. The high Galactic latitude and the lack of CO emission in the direction of S5 0836+710 (Liszt et al. 1993) strongly support an intrinsic origin for the variable absorption.

*Acknowledgements.* AC acknowledges hospitality at the RIKEN Cosmic Radiation Laboratory where part of this work has been done and Dr. T. Di Girolamo for useful discussions.

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